Climate Change Issue Profile: SEA SURFACE TEMPERATURE

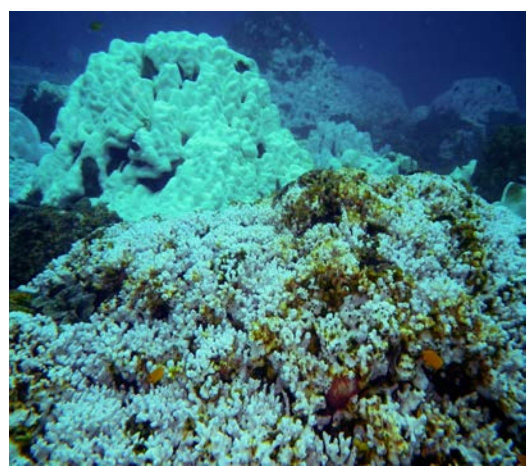
Climate Change and Rising Sea Surface Temperatures:
What can people do to lessen impacts and how can marine protected areas help?

Introduction

The warming of the earth's ocean waters is a major climate change impact that is already being experienced throughout the United States. The world's oceans are warmer now than at any point in the last 50 years (Figure 1). The change is most obvious in the top layer of the ocean, which has grown much warmer since the late 1800s. This top layer is now getting warmer at a rate of 0.2°F per decade.

Polar bears are at risk due to melting sea ice caused by warmer temperatures (credit: Joel Garlich-Miller, US Fish and Wildlife Service)

Marine scientists across the U.S. are noting increased ocean temperatures in many regions. Pershing et al. (2015) reported that between 2004 and 2013, the mean surface temperature of the Gulf of Maine – extending from Cape Cod to Cape Sable in Nova Scotia – rose 4 degrees F, with significant impacts to fish, especially cod, and shifts in ocean currents. Mills et al. (2013) described how the record heat wave of 2012 affected coastal ecosystems and economies along the coast of Maine, with extended fishing season and high landings of lobster brought about by warm water leading to a price collapse received by fishermen at the dock, 70% below normal. In 2014, scientists at the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service noted that the Gulf of Alaska has not been so warm for so long since record keeping began. Scientists associated with the Bering Sea Project (2007-2012) have observed higher sea surface temperature, sightings of tropically-inclined fish species, salmon migrating to the sea and migrating up river at the earliest dates ever recorded, and juvenile salmon growing faster in the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands (Ashjian et al. 2012).



Bleached coral caused primarily by warm ocean water temperatures (credit: NOAA News)

Marine protected areas (MPAs) can play an important role in addressing impacts of climate change and working to build community resilience by controlling local non-climate change stressors such as water pollution, overfishing, and habitat destruction. As place-based and long-term designations, MPAs provide the infrastructure to focus research and monitoring efforts of climate trends, effectively engaging the local community through public education programs, advisory groups, and onsite staff. Familiar examples of MPAs include national parks, national wildlife refuges, national marine sanctuaries, state aquatic preserves, tribal areas, national estuarine research reserves, and state fish and wildlife areas.

While MPAs have legal authority to minimize some local disturbances (e.g., extraction, bottom disturbance, vessel discharge, and development), MPAs are also susceptible to disturbances originating outside their boundaries, at local to global scales, particularly those associated with climate change (e.g., sea-level rise, warming sea surface, ocean acidification, magnitude and frequency of storms, storm surge, spread of invasive species). The warming of ocean waters is increasing as the amount of atmospheric carbon dioxide (CO_2) continues to increase. Scientific laboratories around the country are documenting the physiological impacts of warmer water temperatures to a wide variety of organisms under a variety of possible future ocean water temperature conditions. Understanding the stress of warming ocean water combined with other environmental stressors (e.g., ocean acidification and water quality) in the future is very important to our ocean health.

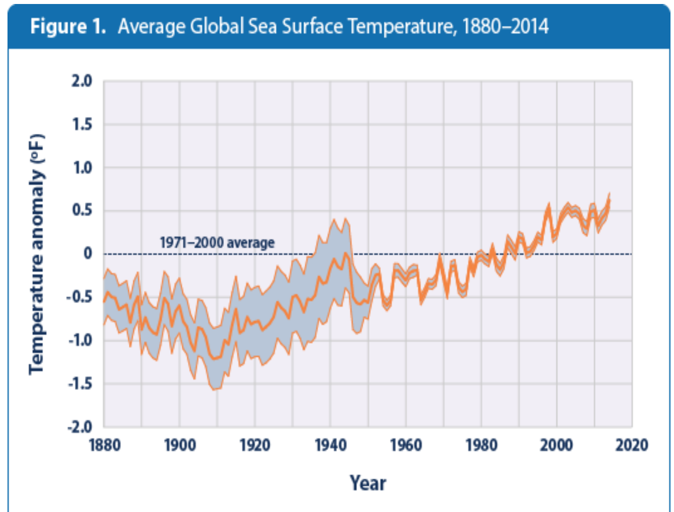


Figure 1. Extended reconstructed sea surface temperature (Credit: National Centers for Environmental Information. Accessed April 2015. www.ncdc.noaa.gov/ersst)

How is ocean water temperature measured?

Temperature (T^0) in the ocean is measured many ways. Many shipboard measurements are "measurements of opportunity" and do not take into account spatial and temporal considerations (e.g., a ship happened to be in a particular place at a particular time). Infrared radiometers on satellites also measure the ocean's surface temperature. The Argo Program (www.argo.avi) is a global array of more than 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. As part of an integrated global observation strategy, ARGO allows for continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection. Scientists combine these measurements with land surface measurements to calculate the global average temperature. The most common ocean temperature measurements are taken at the sea surface. However, scientists can use several other methods to create an extensive large-scale ocean record by using instruments (a) dropped from ships or airplanes (thermistors and mercury thermometers are commonly used on ships and buoys); (b) on remote vehicles that measure the temperature of deep ocean waters, and periodically surface to transfer the information to satellites; and (c) on moorings on the ocean bottom that can measure temperatures at fixed distances above the bottom, until a ship retrieves the instruments—typically after a few months or years. Texas A&M University has put together a primer on various ways to measure ocean water temperature (http://oceanworld.tamu.edu/resources/ocng_textbook/chapter06/chapter06_06.htm).

What causes the ocean to warm?

The ocean acts as a giant sink and stores a large percentage of the Earth's total carbon. As the atmosphere and the ocean make contact with one another, CO_2 is transferred between the two, particularly from the atmosphere to the ocean's surface until the two reach equilibrium. Increased greenhouse gases trap heat in the atmosphere, with less heat escaping from the ocean, altering the ocean's surface temperature. The ocean has absorbed much of the increasing atmospheric CO_2 over the past century, resulting in warmer water.

What are some of the predicted impacts of a rise in ocean sea-surface temperature?

The primary impacts of rising sea-surface temperatures currently being observed and projected to continue include coral bleaching, exacerbation of marine diseases, shifts in the ranges and population abundances of fish and other marine species and the timing of periodic life cycle events (defined as "phenology"), such as when a marine organism breeds, migrates, sheds its shell, etc. Recent studies have shown that in each of the ecosystems sampled (Eastern Bering Sea, Gulf of Alaska, Gulf of Maine, Georges Bank, Norwegian Sea, Barents Sea), fish species showed a general poleward movement in response to warming.

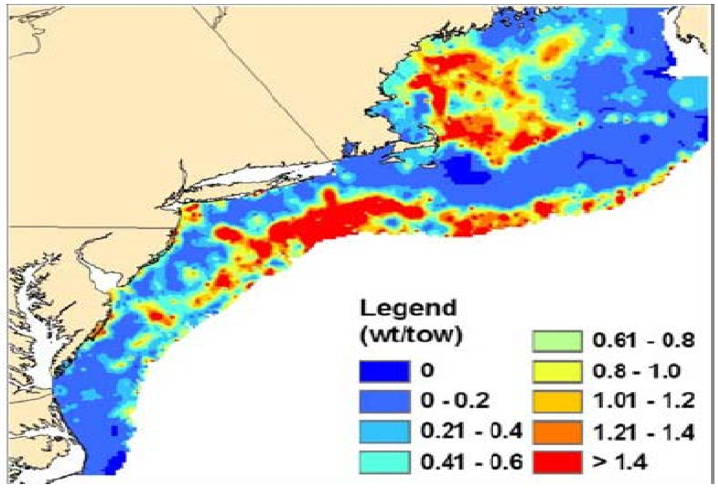


Figure 3. The distribution of red hake in 1973-1977, with the center of the biomass centered south of Long Island and north/northwest of Cape Cod (courtesy of the NOAA Fisheries Service)

NOAA Fisheries Service scientists have documented changes in distribution and abundance for many commercially valuable species in the northwest Atlantic Ocean for decades. The distribution of red hake, for example, was centered south of Long Island in the mid-1970s (Figure 3). In 2005-2009, that center of abundance and distribution had shifted 250 miles north to Cape Cod (Figure 4), with very little abundance found near Long Island. An analysis of 36 fish stocks indicated that the center of biomass in relation to water temperature in the northwest Atlantic exhibited a poleward shift from 1968-2007 (Nye et al. 2009).

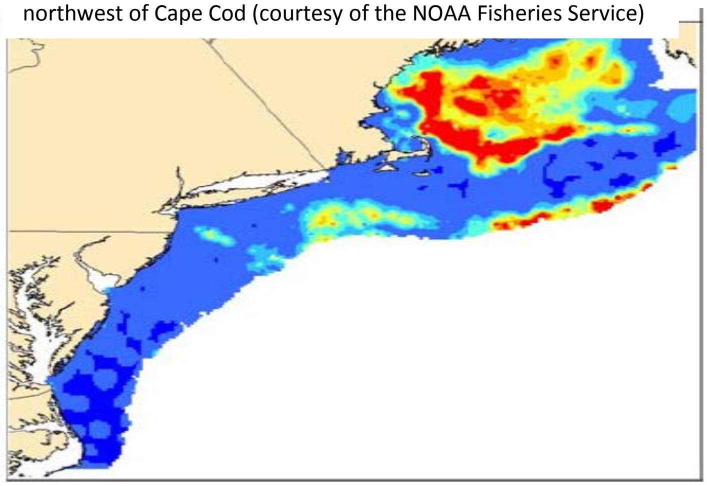


Figure 4. The distribution of red hake in 2005-2009, with the center of the biomass almost disappeared from Long Island, with increased abundance north of Cape Cod (courtesy of NOAA Fisheries Service)

Walsh et al. (2015) compared data collected during NOAA's Marine Resources Monitoring Assessment and Prediction Program from 1977 to 1987, with a similar NOAA data set from 1999 to 2008 that was collected by its Ecosystem Monitoring Program. Their analysis revealed that larvae shifted northward in 43 percent of the taxa, timing of larval occurrence changed in 49% (split evenly between earlier and later) and 75% of depth shifts were to deeper water, making this spatial change consistent with expectations of climate change where species will shift poleward and deeper to seek colder water. Changes in the abundance and location of food (e.g., prey species) will have important ramifications on the availability of many predators. NOAA and Rutgers University have collaborated to develop a web site where a user can see where the general centers of the fish species biomass have changed over time in relation to latitude and depth (www.adapt.rutgers.edu). Loss and degradation of habitats and associated ecological function (e.g., such as suitable nursery and foraging grounds) will be felt by many different organisms, small and large, to changes in water temperature. The NOAA Climate Office cautions that warming ocean temperatures in the Atlantic Ocean may allow for the expansion of tropical fish species (including invasive non-natives such as the Pacific lionfish) into areas formerly too cold for them to thrive. Whitfield et al. (2015) found a strong relationship between warmer water temperatures and abundance and distribution of lionfish off North Carolina. Expansion of predatory lionfish into warming waters will have a negative impact on the abundance of native species.

What are MPAs and their Partners doing to address projected impacts of warming ocean sea surface temperatures?

- Scientists with the Coral Restoration Foundation, Mote Marine Tropical Research Laboratory in the Florida Keys, and The Nature Conservancy are growing heat-resistant corals in laboratory nurseries and transplanting them to reefs in the Florida Keys National Marine Sanctuary (Figure 5). Currently, these are small areas of the reef tract tend to be in need of restoration following disturbance (e.g., bleaching and boat grounding).

- Concerned over the potential impacts of increased increases in sand temperature on sea turtle sex ratios and reproductive success, scientists in Australia and Costa Rica are assessing the effectiveness of sprinkling sea turtle nests with water and providing shade to reduce sand temperature (Figures 6 and 7).

- As the sightings of lionfish spread geographically as water temperatures rise, the Reef Environmental Education Foundation (www.reef.org) has organized "Lionfish Derbies" in the Florida Keys National Marine Sanctuary and adjacent Bahamian waters where anglers and divers removed 14,832 invasive lionfish (Figure 8) from the marine ecosystem from 2009-2014.

- On Boston's historic fish pier, Red's Best Seafood Shop by Networked Fishermen (www.redsbest.com) works closely with fishermen to market the day's catch, not just the historically sought-after species like cod, haddock, and flounder, but also less exploited species often thought as "trash fish" (e.g., porgies, skate). This may prove important in the future to both fishermen and consumers as the distribution and abundance of certain fish species changes. Historically sought-after species may be in lower abundance in the future and fish landings may shift to species that tolerate warmer water temperatures.

Figure 5. Heat-resistant corals grown in the laboratory are transported out to the natural reef (courtesy: Florida Keys National Marine Sanctuary)

Figure 6. Sea turtle nests are sprinkled with water to reduce sand temperatures (courtesy: Dr. Jacob Hill, Indiana University- Ft. Wayne)

Suggested Further Reading

As Ocean Waters Heat Up, A Quest to Create Super Corals http://e360.yale.edu/mobile/feature.msp?id=2900

Ashjian, C.J., H. Rodger Harvey, Michael W. Lomas, Jeffrey M. Napp, Michael F. Sigler, Phyllis J. Stabeno and Thomas I. Van Pelt (Eds.). 2012. Understanding ecosystem processes in the eastern Bering Sea. *Deep Sea Research II Topical Studies in Oceanography* (Vol. 65-70: 1-316).

Environmental Protection Agency. A Student's Guide to Global Climate Change. http://www.epa.gov/climatestudents/impacts/signs/oceans.html

Hill J.E., F.V. Paladino, J.R. Spotila, and P.S. Tomillo. 2015. Shading and Watering as a Tool to Mitigate the Impacts of Climate Change in Sea Turtle Nests. *PLoS ONE* 10(6): e0129528. doi:10.1371/journal.pone.0129528

Figure 7. Sea turtle nests are shaded with canvas to reduce sand temperatures (courtesy: Dr. Jacob Hill, Indiana University-Ft. Wayne)

Mascarelli, Amanda. 2014. Climate-change adaptation: Designer reefs. *Nature* (508) http://www.nature.com/news/climate-change-adaptation-designer-reefs-1.15073

Mills, K.E., A.J. Pershing, C.J. Brown, Y. Chen, F.S. Chiang, D.S. Holland, S. Lehuta, J.A. Nye, J.S. Sun, A.C. Thomas and R.A. Wahle. 2013. Fisheries management in a changing climate: lessons from the 2012 ocean heat wave in the Northwest Atlantic. *Oceanography* Vol. 26 (2):191-195

National Climate Assessment. U.S. Global Change Research Program. http://nca2014.globalchange.gov/

Figure 8. Invasive Pacific lionfish have seen their distribution and abundance expand throughout the South Atlantic and Caribbean (courtesy: Florida Keys National Marine Sanctuary)

Nye, J.A., J.S. Link, J.A. Hare and W.J. Overholtz. 2009. Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. *Mar. Ecol. Prog. Ser.* 393:111-129

Parker, Laura. 2015. As Oceans Heat Up, a Race to Save World's Coral Reefs: Will efforts to save corals be overwhelmed by the quickening pace of climate change? National Geographic Society. Washington, DC. http://news.nationalgeographic.com/news/2015/01/151015/coral-reef-death-climate-change-science-animals/

Pershing, A.J., M.A. Alexander, C.M. Hernandez, L.A. Kerr, A. Le Bris, K.E. Mills, J.A. Nye, N.R. Record, H.A. Scannell, J.D. Scott, G.D. Sherwood and A.C. Thomas. 2015. Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. *Science Magazine* 350 (6262):809-812. www.sciencemag.org/content/350/6262/809

Walsh H.J., D.E. Richardson, K.E. Marancik, and J.A. Hare. 2015. Long-Term Changes in the Distributions of Larval and Adult Fish in the Northeast U.S. Shelf Ecosystem. *PLoS ONE* 10(9):e0137382.doi:10.1371/journal.pone.0137382

Whitfield, P. E., Muñoz, R. C., Buckel, C. A., Degan, B. P., Freshwater, D. W., & Hare, J. A. (2014). Native fish community structure and Indo-Pacific lionfish *Pterois volitans* densities along a depth-temperature gradient in Onslow Bay, North Carolina, USA. *Mar. Ecol. Prog. Ser. 509*, 241–254. doi:10.3354/meps10882

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